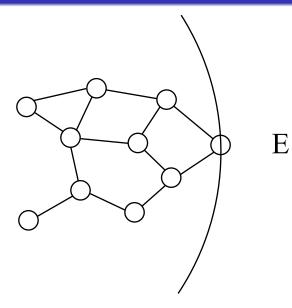
Introduction	Definitions	Solution overview	Cut-off definitions	Conclusion

# Computation of Summaries Using Net Unfoldings

# Loïg Jezequel joint work with Javier Esparza and Stefan Schwoon

FSTTCS December 12-24, 2013 Introduction Cut-off definitions

# The summary problem



Introduction	Definitions 00	Solution overview	Cut-off definitions	Conclusion
The sum	mary probler	m		

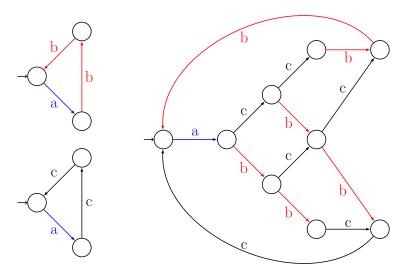


Introduction	Definitions	Solution overview	Cut-off definitions	Conclusion

# Some definitions

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Introduction Definitions Solution overview Cut off definitions Conclusion	Introduction	Solution overview 0000000	Cut-off definitions	Conclusion

### Problem representation: LTSs, parallel composition



Introduction Definitions		Solution overview	Cut-off definitions	Conclusion
The sum	mary proble	m in terms of I	ΤSc	

#### Summary with interface $A_i$

Given  $A_1, A_2, \ldots, A_n$ , LTSs Given  $A_i$ , distinguished LTS with set of labels  $\Sigma_i$ Find an LTS  $S_i$  such that:

$$S_i \equiv (A_1 || \dots || A_n) \setminus \overline{\Sigma_i}$$

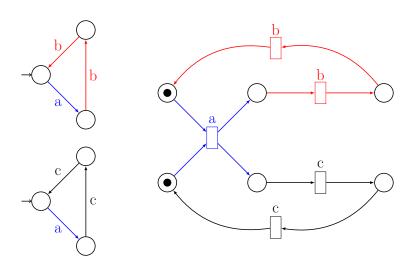
 $\begin{array}{l} || \text{ parallel composition} \\ \underline{\setminus} \text{ hiding} \\ \overline{\Sigma} \text{ complement} \end{array}$ 

Introduction	Definitions	Solution overview	Cut-off definitions	Conclusion

# Solution overview

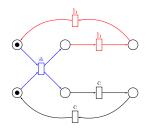


### Use concurrency: parallel composition as a Petri net





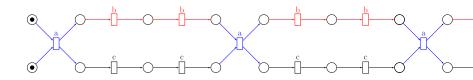
# Use concurrency: unfolding



#### Unfolding algorithm

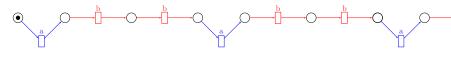
input: a (safe) Petri net *P* output: its unfolding *N* 

initialize N from the marked places of P while  $Ext(N, P) \neq \emptyset$ choose  $e \in Ext(N, P)$ extend N with e







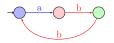










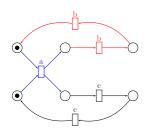


#### Equivalence classes

Will be defined using information from the unfolding



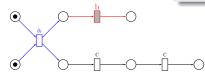
### Use concurrency: cut-off events



#### Unfolding algorithm

input: a (safe) Petri net P
output: a prefix of its unfolding N

initialize N from the marked places of P initialize co as an empty set while  $Ext(N, P, co) \neq \emptyset$ choose  $e \in Ext(N, P)$ extend N with e if e is cut-off then  $co \leftarrow co \cup \{e\}$ 



#### Goal

- Finite prefix
- Preserves relevant properties



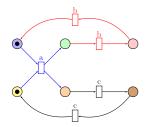
Find a definition of cut-offs and a definition of equivalence relation so that given  $A_1, A_2, \ldots, A_n$ , given  $A_i$  with set of labels  $\Sigma_i$ ,

 $S_i = Folding(Interface(Unfolding(A_1||...||A_n)))$ 

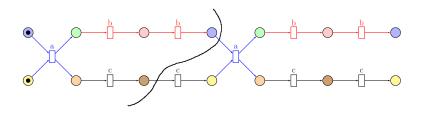
is a solution to the summary problem with interface  $A_i$ :

 $S_i \equiv (A_1 || \dots || A_n) \setminus \overline{\Sigma_i}$ 

Introduction	Definitions 00	Solution overview 000000●	Cut-off definitions	Conclusion
Equivalence	e relation			

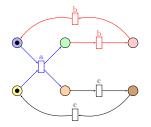


### Configuration

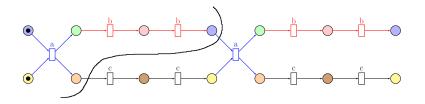


Introduction	Definitions 00	Solution overview	Cut-off definitions	Conclusion
Fauivaler	nce relation			

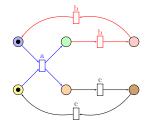




### Minimal configuration, global state



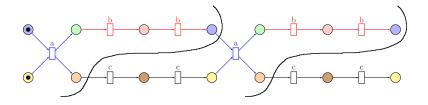
Introduction	Definitions 00	Solution overview 000000●	Cut-off definitions	Conclusion
Equivalen	ce relation			



Configuration

Minimal configuration, global state

### Equivalent places



Introduction	Definitions	Solution overview	Cut-off definitions	Conclusion

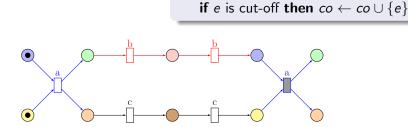
# Cut-off definitions

Introduction	Definitions 00		ion overview 2000	Cut-off definitions ●0000	Conclusion	
Cut-off definition for non-divergent systems						
			Unfolding a	algorithm		
Cut-off defin	ition		input: a (s	afe) Petri net <i>P</i>		
An event <i>e</i> i	s cut-off if:		•	<b>prefix</b> of its unfoldir	ng N	
	interface event,		initialize A	/ from the marked p	laces of P	
	kists an interfac		initialize c	o as an empty set		

while  $Ext(N, P, co) \neq \emptyset$ 

extend N with e

choose  $e \in Ext(N, P)$ 



event e' in N such that e'

and e' correspond to the

same global state.

Introduction	Definitions 00	Solution overview	Cut-off definitions •0000	Conclusion
	C tot C	12		

### Cut-off definition for non-divergent systems

#### Cut-off definition

An event e is cut-off if:

- it is an interface event, and
- there exists an interface event e' in N such that e and e' correspond to the same global state.

#### Non-divergent system

Any infinite execution involves an infinite number of transitions from  $A_i$ .

#### Theorem

- If  $A_1 || \dots || A_n$  is non-divergent then
  - N is finite, and
  - Folding(Interface(N)) is a solution to the summary problem.



## Cut-off definition for divergent systems

#### Cut-off definition

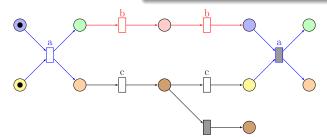
An event *e* is cut-off if:

- it is an interface event, and
- there exists an interface event e' in N such that e and e' correspond to the same global state.

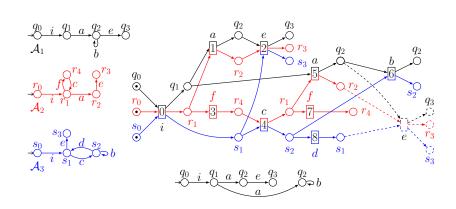
#### Addition to the cut-off definition

An event *e* is cut-off if:

- it is not an interface event, and
- there exists an event e' < e in N such that
  - *e* and *e'* correspond to the same global state, and
  - *e* and *e'* correspond to the same interface condition.



Introduction	Definitions 00	Solution overview	Cut-off definitions	Conclusion
Counter e	example			



Introduction	Definitions 00	Solution overview	Cut-off definitions	Conclusion
Cut-off c	andidates			

#### Idea

Non-interface events will not be proper cut-offs but temporary cut-offs:

- stops unfolding as cut-off events,
- can be freed (i.e. stop to be cut-off).

Introduction	Definitions 00	Solution overview 0000000	Cut-off definitions 0000●	Conclusion
Cut-off d	efinition for	divergent syste	ems	

#### Cut-offs

An event e is cut-off if:

- it is an interface event, and
- there exists an interface event e' in N such that e and e' correspond to the same global state.

Introduction		Solution overview	Cut-off definitions 0000●	Conclusion		
Cut-off de	Cut-off definition for divergent systems					
Cut-offs		Cut-off candida	ates			
An event <i>e</i> is	s cut-off if:	An event <i>e</i> is a	a cut-off candidate i	f:		
• it is an i	nterface event, and	• it is not a	n interface event, a	nd		
event e' and e' co	ists an interface in N such that e orrespond to the obal state.	such that • e and global • e and interfa • if e is event	is an event $e' \ll e$ in e' correspond to the state, e' correspond to the ace condition, and concurrent with an i e'' (not cut-off), the oncurrent with $e''$ .	same same nterface		
e						

Introduction	Definitions 00	Solution overview 0000000	Cut-off definitions	Conclusion	
Cut-off definition for divergent systems					
Cut-offs		Cut-off candic	lates		
An event <i>e</i> is	cut-off if:	An event <i>e</i> is	a cut-off candidate	if:	
• it is an i	nterface event, and	d 🔹 it is not a	an interface event,	and	
<ul> <li>It is an interface event, and</li> <li>there exists an interface event e' in N such that e and e' correspond to the same global state.</li> </ul>		such that • e an globa • e an inter • if e i even	<ul> <li>there exists an event e'≪e in N such that</li> <li>e and e' correspond to the same global state,</li> <li>e and e' correspond to the same interface condition, and</li> <li>if e is concurrent with an interface event e'' (not cut-off), then e' is also concurrent with e''.</li> </ul>		
		Free candidat	es		
e			ees a cut-off candidate a cut-off candidate with <i>e</i> .		

Introduction	Definitions 00	Solution overview	Cut-off definitions	Conclusion

# To conclude

Introduction	Definitions	Solution overview	Cut-off definitions	Conclusior

# To conclude

#### Contributions

- Unfoldings for computing summaries:
  - for traces (experimental analysis in the paper)
  - for weighted traces (in the paper)
  - for divergences (in the paper)
- Notion of cut-off candidates

#### Future work

- Strong causality
- Other semantics:
  - deadlocks
  - timed traces



Paper with proofs available on arXiv.org arXiv:1310.2143